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Wang et al.

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(54) **EJECTOR CYCLE REFRIGERANT SEPARATOR**

(75) Inventors: **Jinliang Wang**, Ellington, CT (US); **Parmesh Verma**, Manchester, CT (US); **David P. Martin**, East Hartford, CT (US); **Frederick J. Cogswell**, Glastonbury, CT (US)

(73) Assignee: **Carrier Corporation**, Farmington, CT (US)

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F25B 43/00 (2006.01)
F25B 41/00 (2006.01)

(52) **U.S. Cl.**

CPC ***F25B 43/00*** (2013.01); ***F25B 41/00*** (2013.01); ***F25B 43/006*** (2013.01); *F25B 2341/0011* (2013.01); *F25B 2400/03* (2013.01); *F25B 2400/13* (2013.01)

(58) **Field of Classification Search**

CPC F25B 43/02; F25B 31/004; F25B 2341/0012; F25B 2400/23
USPC 62/470, 500, 503, 511, 512
See application file for complete search history.

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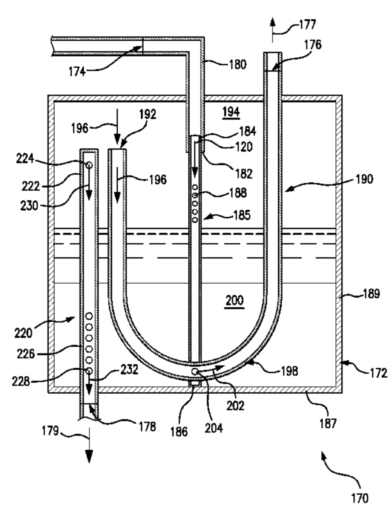
Primary Examiner — Melvin Jones
(74) *Attorney, Agent, or Firm* — Bachman & LaPointe, P.C.

(57) **ABSTRACT**

A system has a compressor (**22**, **412**). A heat rejection heat exchanger (**30**) is coupled to the compressor to receive refrigerant compressed by the compressor. The system has a heat absorption heat exchanger (**64**). The system includes a separator (**170**) comprising a vessel having an interior. The separator has an inlet, a first outlet, and a second outlet. An inlet conduit may extend from the inlet and may have the conduit outlet positioned to discharge an inlet flow into the vessel interior to cause the inlet flow to hit a wall before passing to a liquid refrigerant accumulation in the vessel.

20 Claims, 4 Drawing Sheets



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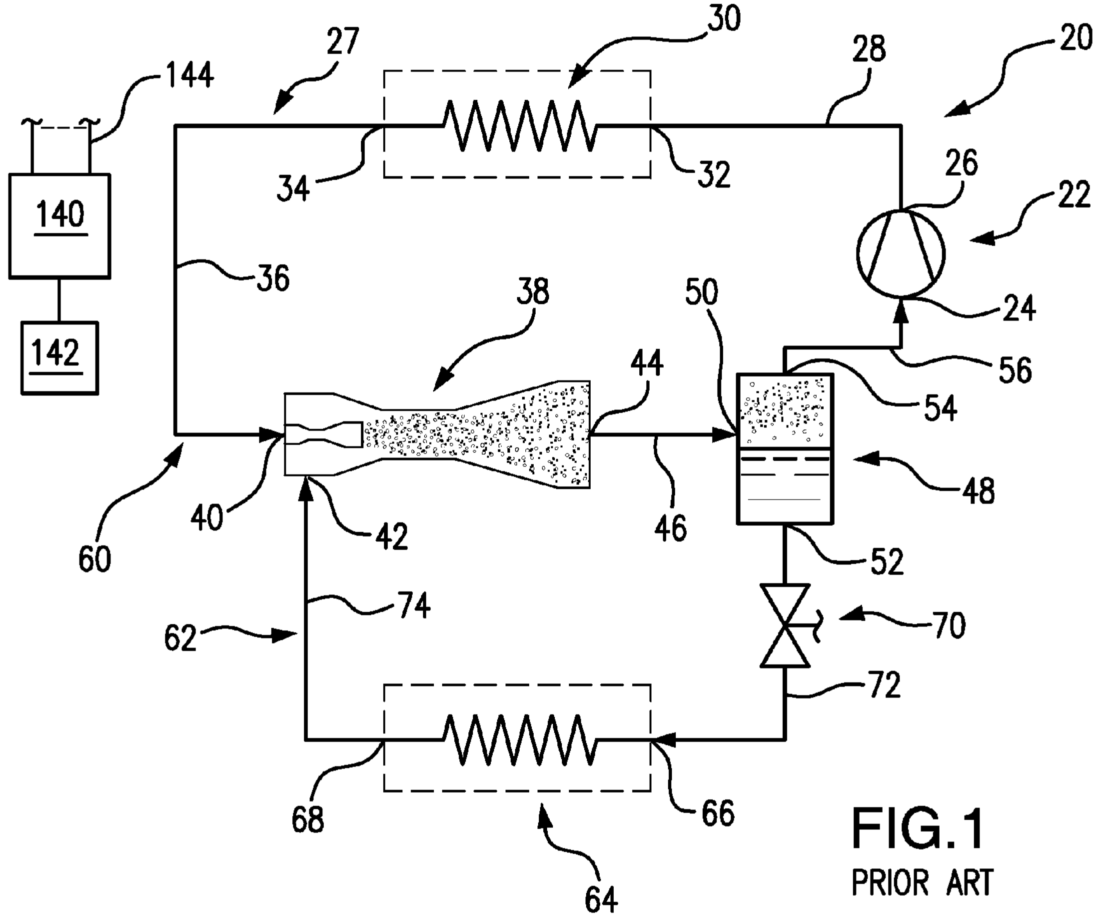


FIG.1
PRIOR ART

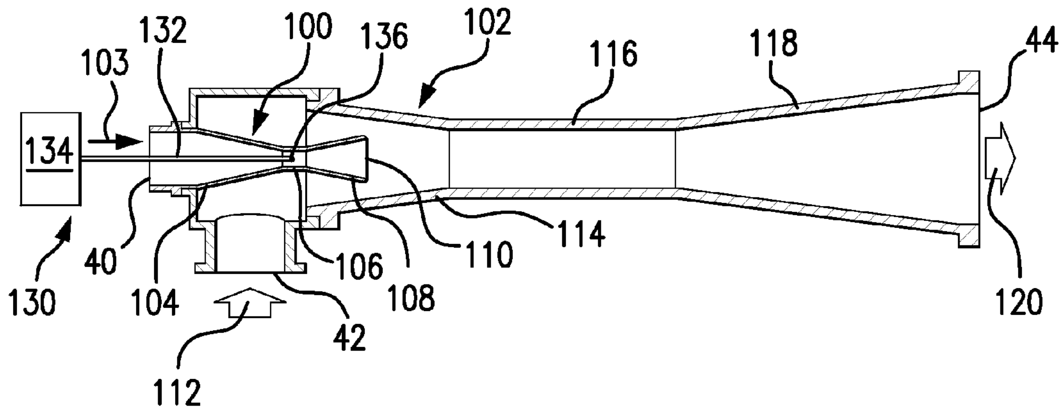
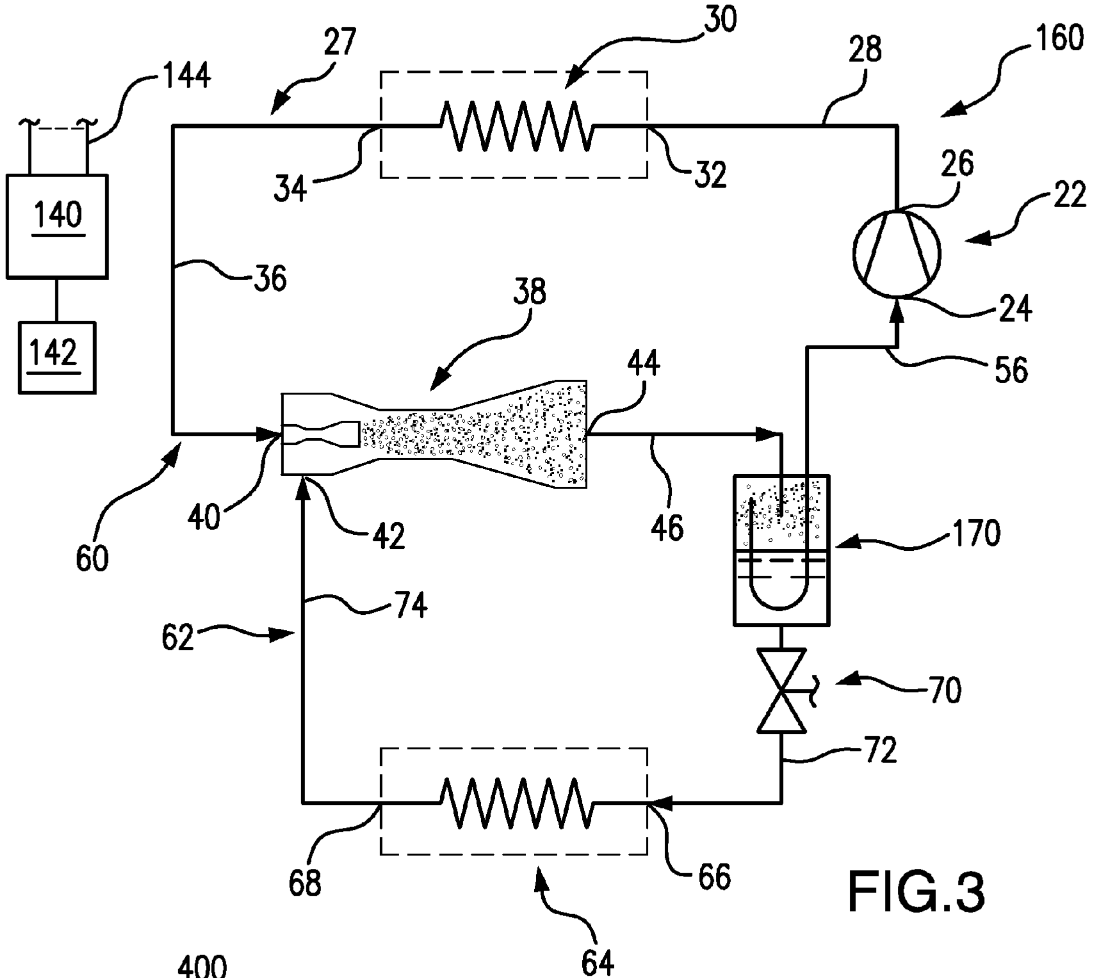


FIG. 2
PRIOR ART



144
140
142
27
30
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34
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170
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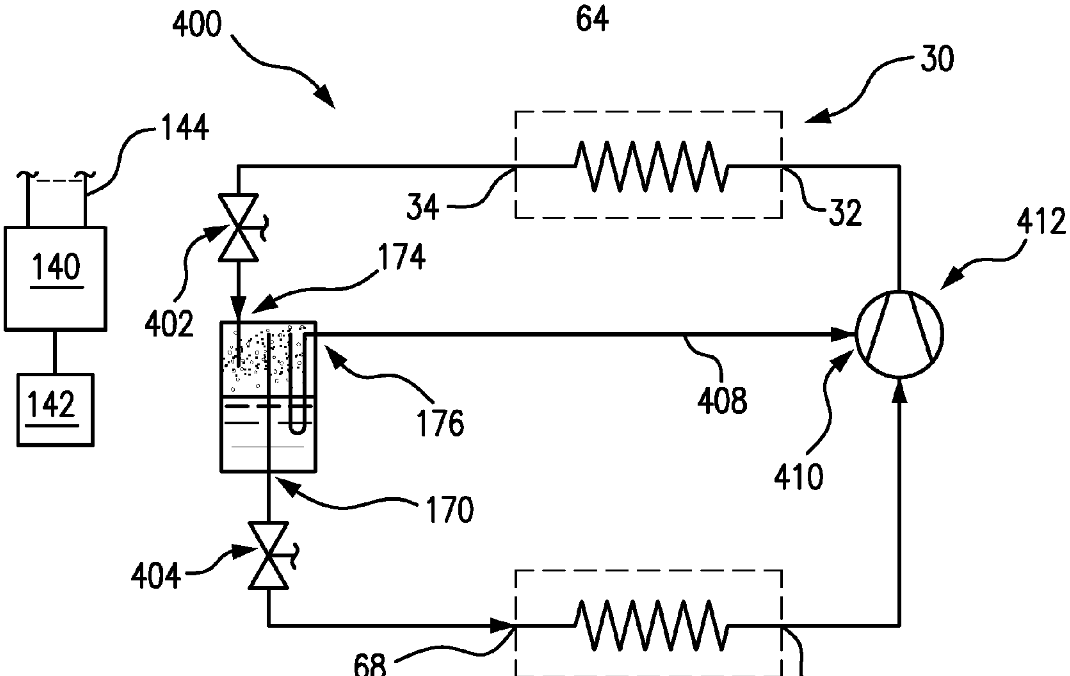
62
70
72
68
66
64

FIG.3



400
144
30
140
34
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402
174
142
176
408
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170
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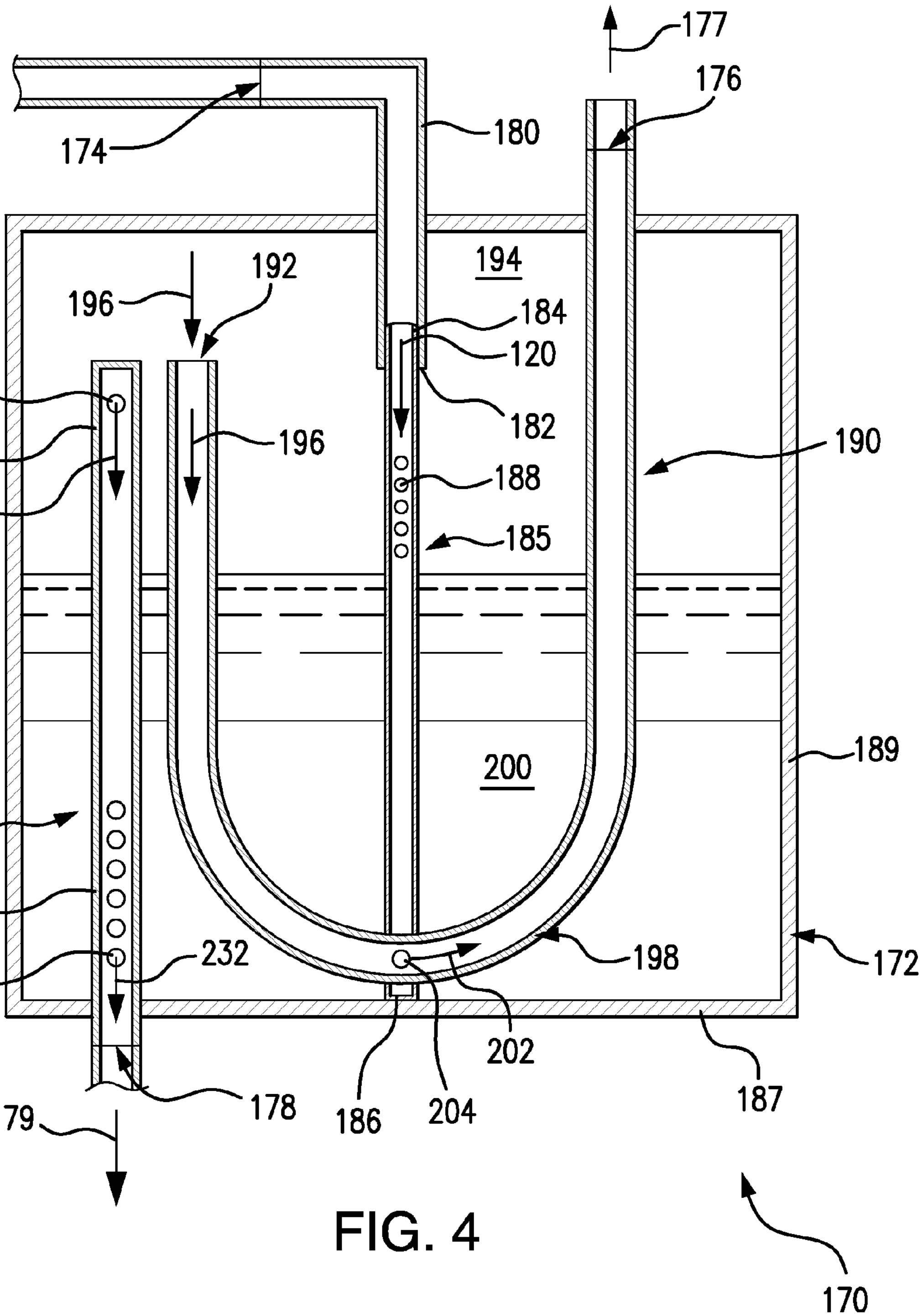
68
66
64

FIG.11


177
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120
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182
222
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190
230
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220
226
232
198
172
228
202
186
204
187
179
178
170

FIG. 4

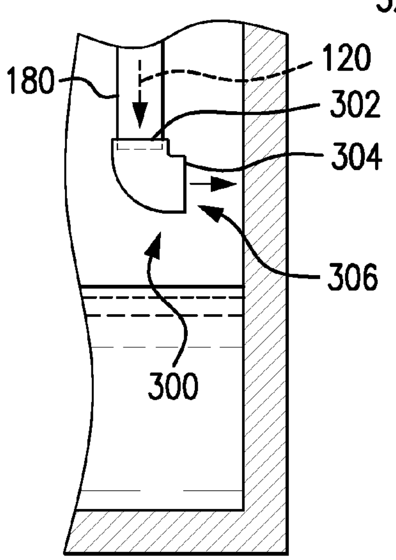

FIG. 5

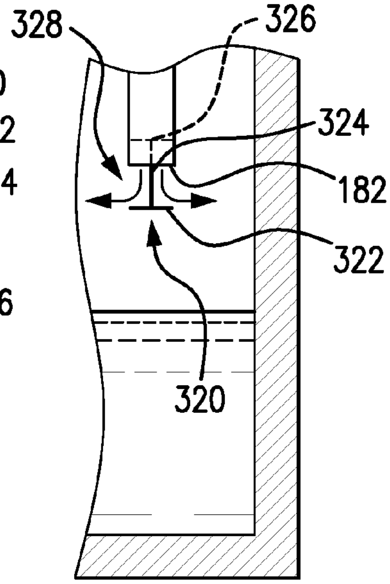

FIG. 6

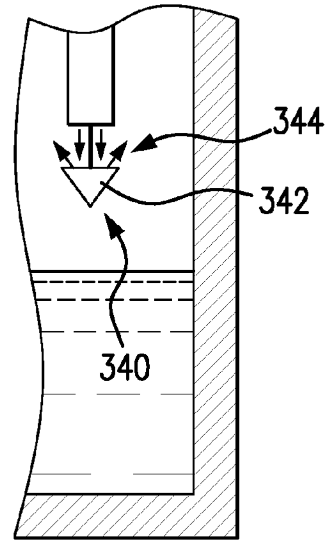

FIG. 7

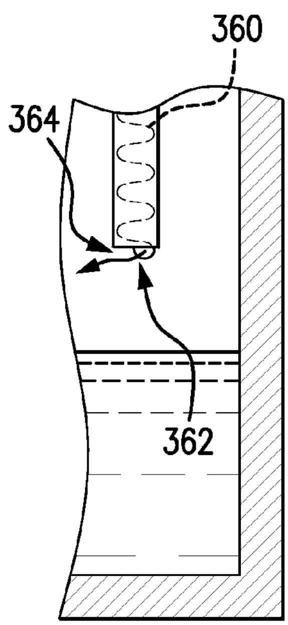

FIG. 8

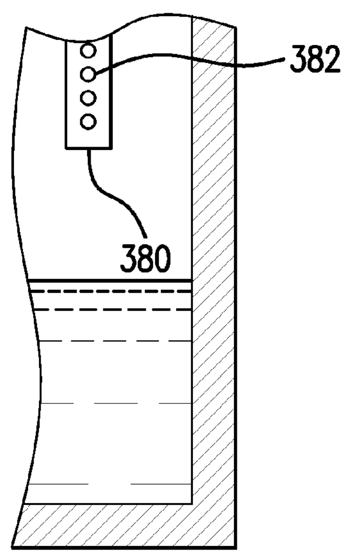

FIG. 9

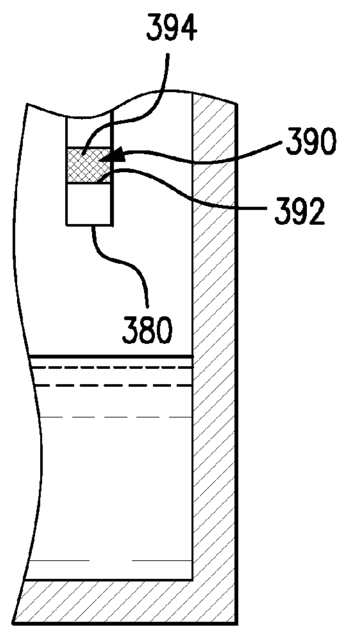

FIG. 10

EJECTOR CYCLE REFRIGERANT SEPARATOR

CROSS-REFERENCE TO RELATED APPLICATION

Benefit is claimed of U.S. Patent Application Ser. No. 61/367,086, filed Jul. 23, 2010, and entitled "Ejector Cycle Refrigerant Separator", the disclosure of which is incorporated by reference herein in its entirety as if set forth at length.

BACKGROUND

The present disclosure relates to refrigeration. More particularly, it relates to refrigerant separators.

Earlier proposals for ejector refrigeration systems are found in U.S. Pat. No. 1,836,318 and U.S. Pat. No. 3,277,660. FIG. **1** shows one basic example of an ejector refrigeration system **20**. The system includes a compressor **22** having an inlet (suction port) **24** and an outlet (discharge port) **26**. The compressor and other system components are positioned along a refrigerant circuit or flowpath **27** and connected via various conduits (lines). A discharge line **28** extends from the outlet **26** to the inlet **32** of a heat exchanger (a heat rejection heat exchanger in a normal mode of system operation (e.g., a condenser or gas cooler)) **30**. A line **36** extends from the outlet **34** of the heat rejection heat exchanger **30** to a primary inlet (liquid or supercritical or two-phase inlet) **40** of an ejector **38**. The ejector **38** also has a secondary inlet (saturated or superheated vapor or two-phase inlet) **42** and an outlet **44**. A line **46** extends from the ejector outlet **44** to an inlet **50** of a separator **48**. The separator has a liquid outlet **52** and a gas outlet **54**. A suction line **56** extends from the gas outlet **54** to the compressor suction port **24**. The lines **28**, **36**, **46**, **56**, and components therebetween define a primary loop **60** of the refrigerant circuit **27**. A secondary loop **62** of the refrigerant circuit **27** includes a heat exchanger **64** (in a normal operational mode being a heat absorption heat exchanger (e.g., evaporator)). The evaporator **64** includes an inlet **66** and an outlet **68** along the secondary loop **62** and expansion device **70** is positioned in a line **72** which extends between the separator liquid outlet **52** and the evaporator inlet **66**. An ejector secondary inlet line **74** extends from the evaporator outlet **68** to the ejector secondary inlet **42**.

In the normal mode of operation, gaseous refrigerant is drawn by the compressor **22** through the suction line **56** and inlet **24** and compressed and discharged from the discharge port **26** into the discharge line **28**. In the heat rejection heat exchanger, the refrigerant loses/rejects heat to a heat transfer fluid (e.g., fan-forced air or water or other fluid). Cooled refrigerant exits the heat rejection heat exchanger via the outlet **34** and enters the ejector primary inlet **40** via the line **36**.

The exemplary ejector **38** (FIG. **2**) is formed as the combination of a motive (primary) nozzle **100** nested within an outer member **102**. The primary inlet **40** is the inlet to the motive nozzle **100**. The outlet **44** is the outlet of the outer member **102**. The primary refrigerant flow **103** enters the inlet **40** and then passes into a convergent section **104** of the motive nozzle **100**. It then passes through a throat section **106** and an expansion (divergent) section **108** through an outlet **110** of the motive nozzle **100**. The motive nozzle **100** accelerates the flow **103** and decreases the pressure of the flow. The secondary inlet **42** forms an inlet of the outer member **102**. The pressure reduction caused to the primary flow by the motive nozzle helps draw the secondary flow **112** into the outer member. The outer member includes a (mixer having a convergent) section **114** and an elongate throat or mixing section **116**. The outer member also has a divergent section or diffuser **118** downstream of the elongate throat or mixing section **116**. The motive nozzle outlet **110** is positioned within the secondary nozzle convergent section **114**. As the flow **103** exits the outlet **110**, it begins to mix with the flow **112** with further mixing occurring through the mixing section **116** which provides a mixing zone. In operation, the primary flow **103** may typically be supercritical upon entering the ejector and subcritical upon exiting the motive nozzle. The secondary flow **112** is gaseous (or a mixture of gas with a smaller amount of liquid) upon entering the secondary inlet port **42**. The resulting combined flow **120** is a liquid/vapor mixture and decelerates and recovers pressure in the diffuser **118** while remaining a mixture. Upon entering the separator, the flow **120** is separated back into the flows **103** and **112**. The flow **103** passes as a gas through the compressor suction line as discussed above. The flow **112** passes as a liquid to the expansion valve **70**. The flow **112** may be expanded by the valve **70** (e.g., to a low quality (two-phase with small amount of vapor)) and passed to the evaporator **64**. Within the evaporator **64**, the refrigerant absorbs heat from a heat transfer fluid (e.g., from a fan-forced air flow or water or other liquid) and is discharged from the outlet **68** to the line **74** as the aforementioned gas.

Use of an ejector serves to recover pressure/work. Work recovered from the expansion process is used to compress the gaseous refrigerant prior to entering the compressor. Accordingly, the pressure ratio of the compressor (and thus the power consumption) may be reduced for a given desired evaporator pressure. The quality of refrigerant entering the evaporator may also be reduced. Thus, the refrigeration effect per unit mass flow may be increased (relative to the non-ejector system). The distribution of fluid entering the evaporator is improved (thereby improving evaporator performance). Because the evaporator does not directly feed the compressor, the evaporator is not required to produce superheated refrigerant outflow. The use of an ejector cycle may thus allow reduction or elimination of the superheated zone of the evaporator. This may allow the evaporator to operate in a two-phase state which provides a higher heat transfer performance (e.g., facilitating reduction in the evaporator size for a given capability).

The exemplary ejector may be a fixed geometry ejector or may be a controllable ejector. FIG. **2** shows controllability provided by a needle valve **130** having a needle **132** and an actuator **134**. The actuator **134** shifts a tip portion **136** of the needle into and out of the throat section **106** of the motive nozzle **100** to modulate flow through the motive nozzle and, in turn, the ejector overall. Exemplary actuators **134** are electric (e.g., solenoid or the like). The actuator **134** may be coupled to and controlled by a controller **140** which may receive user inputs from an input device **142** (e.g., switches, keyboard, or the like) and sensors (not shown). The controller **140** may be coupled to the actuator and other controllable system components (e.g., valves, the compressor motor, and the like) via control lines **144** (e.g., hardwired or wireless communication paths). The controller may include one or more: processors; memory (e.g., for storing program information for execution by the processor to perform the operational methods and for storing data used or generated by the program(s)); and hardware interface devices (e.g., ports) for interfacing with input/output devices and controllable system components.

Various modifications of such ejector systems have been proposed. One example in US20070028630 involves placing a second evaporator along the line **46**. US20040123624 discloses a system having two ejector/evaporator pairs. Another two-evaporator, single-ejector system is shown in US20080196446.

SUMMARY

One aspect of the disclosure involves a system having a compressor. A heat rejection heat exchanger is coupled to the compressor to receive refrigerant compressed by the compressor. The system has a heat absorption heat exchanger. The system includes a separator comprising a vessel having an interior. The separator has: an inlet; a first outlet; and a second outlet. An inlet conduit may extend from the inlet and may have the conduit outlet positioned to discharge an inlet flow into the vessel interior to cause the inlet flow to hit a wall before passing to a liquid refrigerant accumulation in the vessel.

In various implementations, an ejector may have: a primary inlet coupled to the heat rejection heat exchanger to receive refrigerant: a secondary inlet; and an outlet. The separator inlet may be coupled to an outlet of the ejector. An expansion device may be immediately upstream of the heat absorption heat exchanger. The refrigerant may comprise at least 50% carbon dioxide, by weight. The separator may also be used as a flash tank device for an economized cycle.

Other aspects of the disclosure involve methods for operating the system.

The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a prior art ejector refrigeration system.

FIG. **2** is an axial sectional view of an ejector.

FIG. **3** is a schematic view of a first refrigeration system.

FIG. **4** is an enlarged view of a separator of the system of FIG. **3**.

FIG. **5** is a partial, partially schematic, cutaway view of an alternate separator.

FIG. **6** is a partial, partially schematic, cutaway view of a second alternate separator.

FIG. **7** is a partial, partially schematic, cutaway view of a third alternate separator.

FIG. **8** is a partial, partially schematic, cutaway view of a fourth alternate separator.

FIG. **9** is a partial, partially schematic, cutaway view of a fifth alternate separator.

FIG. **10** is a partial, partially schematic, cutaway view of a sixth alternate separator.

FIG. **11** is a schematic view of a second refrigeration system.

Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

FIG. **3** shows an ejector cycle vapor compression (refrigeration) system **160**. The system **160** may be made as a modification of the system **20** or of another system or as an original manufacture/configuration. In the exemplary embodiment, like components which may be preserved from the system **20** are shown with like reference numerals. Operation may be similar to that of the system **20** except as discussed below with the controller controlling operation responsive to inputs from various temperature sensors and pressure sensors.

The separator **48** of FIG. **1** is replaced with a separator that may more resemble an existing accumulator (e.g., is made or designed as a modification of an existing accumulator). The modification may add an additional outlet to the existing/baseline accumulator to form a separator liquid outlet. It may be desirable to avoid high velocity impact of the inlet flow with the accumulation in the separator. Such impact might cause foaming which could provide undesirable introduction of vapor refrigerant into the accumulation and therefrom through the liquid outlet. As is discussed further below, means are provided for deflecting the inlet flow to reduce the velocity with which the inlet flow encounters the accumulation.

Nevertheless, it may be desirable to provide a controlled amount of mixed phase outlet flow (e.g., a slight amount of vapor discharged through the liquid outlet and/or a slight amount of liquid discharged through the vapor or gas outlet). Means for providing such mixed phase flow may also be provided if desired. For example, by feeding a two-phase mixture into the compressor, the discharge temperature of the compressor can be reduced if desired (thus extending the compressor system operating range). Feeding a suction line heat exchanger (SLHX) and/or compressor with small amount liquid are also expected to improve both SLHX and compressor efficiency. Exemplary refrigerant is delivered as 85-99% quality (vapor mass flow percentage), more narrowly, 90-98% or 94-98%. Also by feeding a two-phase mixture to the expansion valve upstream of the evaporator one can precisely control the system capacity, which can prevent unnecessary system shutdowns (comfort and improved reliability) and improve temperature control. This may help improve refrigerant distribution in the evaporator manifold and further improve evaporator performance Exemplary refrigerant is delivered as 1-10% quality (vapor mass flow percentage), more narrowly 2-6%.

The exemplary separator **170** (FIG. **4**) may be based upon a conventional accumulator. The modified accumulator has a tank or vessel **172**, an inlet **174**, a first outlet **176** for discharging the vapor (or high quality) refrigerant **177**, and a second outlet **178** for discharging the liquid (or low quality) refrigerant **179**. The baseline accumulator has an inlet conduit **180** which extends to a downstream end **182** which would otherwise form the outlet of the inlet conduit. The exemplary end **182** is within a headspace **194** which would be above the accumulation **200**. The baseline accumulator is modified by inserting an upper end **184** of a tube insert **185** into the inlet conduit (and securing via welding, clamping, or the like). The conduit **182** thus becomes a first member/portion of the resulting inlet conduit (assembly) while the insert **185** becomes the second member/portion.

A lower end **186** of the tube insert **185** is closed and sits on the bottom **187** of the vessel (e.g., for support so as to minimize stress on the joint with the inlet conduit **182**). Along an intermediate portion (still above a surface of the accumulation **200**) the tube insert **185** bears apertures (holes) **188**. The apertures **188** deflect the inlet flow **120** to reduce the velocity with which the inlet flow encounters the accumulation. For example, the apertures **188** may cause the inlet flow to deflect off the inner surface of the sidewall **189** of the vessel (e.g., flow down the sidewall to the accumulation). This deflection reduces foaming in the accumulation **200** and helps provide controlled balances of vapor and liquid in the flows **177** and **179**.

In one exemplary implementation, the inlet tube has an inner diameter (ID) of 15.9 mm which corresponds to a particular standard tube size. Other sizes may be used depending upon system requirements.

In the example, the holes **188** are grouped in two rows of five holes with each hole of one group diametrically opposite an associated hole of the other group. The exemplary holes are 0.25 inch (6.35 mm) in diameter. Other patterns of holes may be provided. For example, the patterns may be provided to create specific flow patterns, to accommodate other internal components, or the like. Similarly, hole orientation may be varied off radial or off horizontal. For example, angling of the holes upward at angles of up to 45° off horizontal/radial may allow the flows along the sidewall to use more of the sidewall. More broadly, an exemplary tube size for the inlet conduit or an insert therein is one eighth of an inch to two inches (3.2 mm-50.8 mm). Similarly, an exemplary range of hole sizes (especially for drilled holes) is 0.8 mm-20 mm in diameter depending upon the desired flow rate, conduit size, etc. Non-circular holes may have similar exemplary cross-sectional areas. An exemplary ratio of total hole area to local tube internal cross-sectional area is 0.5-20, more narrowly 1-5 or 1-2.

The exemplary first outlet **176** is at the downstream end of a U-tube (or J-tube) **190**. The U-tube extends to a second end (gas inlet end) **192** open to the headspace **194** of the tank for drawing a flow **196** of gas from the headspace. A lower portion (trough or base) **198** of the U-tube is immersed in the liquid refrigerant accumulation **200** in a lower portion of the tank, below the headspace. To entrain the desired amount of liquid **202** into the gas flow to form the high quality flow **177**, one or more holes **204** may be formed along the U-tube, including in the lower portion **198**. The hole sizing and locations are configured to provide the desired quality of two phase mixture entering the SLHX and/or compressor. An exemplary hole size for a drilled hole is 0.01 inch-0.5 inch (0.25 mm-12.7 mm), more narrowly 0.2-0.3 inch (5.1-7.6 mm). Multiple holes may be used and may be placed to achieve desired results.

To provide the small amount of gas in the low quality flow **179**, one or more vapor line tubes **220** may extend from a portion **222** having one or more gas inlets (holes) **224** in the headspace. An exemplary portion **222** is a closed end upper portion. A second portion **226** (a lower portion) has one or more holes **228** within the liquid accumulation **200**. The sizes of the holes **228** and **224** are selected so that a flow **230** of gaseous refrigerant is drawn through the holes **224** and becomes entrained in a flow of liquid refrigerant **232** drawn through the holes **228** to provide the desired composition of the low quality flow **179**. Exemplary size for the holes **224** is up to two inches (50 mm) in diameter for drilled holes or equivalent area for others, more narrowly, 0.1-0.5 inches (2.5-13 mm) or 0.1-0.3 inches (2.5-7.6 mm). Exemplary size for the holes **228** is 0.1-2 inches in diameter for drilled holes or equivalent area for others, more narrowly f 0.2-1.0 inches (5-25 mm) or 0.25-0.75 inches (6.35-19.1 mm). The ratio of hole sizes (**224** vapor to **228** liquid) is 0 to 0.9; more narrowly 0.1 to 0.5; more narrowly 0.1 to 0.3.

FIGS. **5-10** show alternate separators which may otherwise be similar to the separator of FIG. **4**. In FIG. **5**, the flow **120** is directed directly to the vessel sidewall (e.g., via an elbow **300**) having a first end **302** attached to the inlet conduit **180** and a second end **304** (forming an outlet **306** of the resulting inlet conduit) in close facing proximity to the sidewall to discharge the flow directly against the sidewall. The elbow **300** may be of an appropriate existing fitting type compatible with the inlet conduit.

FIG. **6** shows a diverter **320** having a plate **322** (e.g., a round flat metallic plate) held spaced apart from the inlet conduit end **182** (e.g., via a metal or other shaft **324**) mounted to a spider or other spacer **326** which is mounted to the inlet conduit (e.g., via welding, brazing, or the like). The annular gap **328** between the rim/outlet **182** of the conduit first portion and the plate **322** thus becomes the outlet of the resulting conduit assembly. The exemplary inlet flow is deflected laterally by the plate to impact the sidewall.

FIG. **7** shows an alternate diverter **340** which may be otherwise similar to the alternate diverter **320**. However, the plate is replaced by a conical or otherwise upwardly concave structure **342**. Similar to the diverter **320**, the annular space/gap **344** becomes the effective outlet of the conduit assembly. This configuration deflects the inlet flow back upward to impact higher along the sidewall and at a lower angle of incidence to yet further reduce possibilities of entraining vapor during the impact.

FIG. **8** shows a helical baffle **360** inserted within the inlet conduit **182** and mounted thereto (e.g., via welding, brazing, or the like). The baffle may slow the flow and encourage separation of the vapor and liquid as the inlet flow flows along the baffle. The baffle may also cause a lateral discharge of the inlet flow to impact the sidewall as in other embodiments. For example, the positioning of a lower end portion **362** of the baffle **360** may provide an effective opening **364** below the conduit end **182** of the conduit first portion.

FIG. **9** shows the downstream end **380** of the inlet conduit closed off relative to the baseline end **182**. Holes **382** may be positioned along the inlet conduit and may function in a similar fashion to the holes **188**. Alternatively, the holes may be formed along an insert with the end being above the vessel bottom and not supported thereby.

FIG. **10** replaces the holes **382** with the apertures **394** of a foraminate member **390** (e.g., a mesh or perforated sheet) secured across a large lateral aperture/opening **392**. An exemplary foraminate member has an open area percentage of 10-95%, more narrowly, 20-80% or 50-70%. An exemplary pore size (e.g., a diameter of a circular pore or a length/width of a square mesh pore) is 0.01 inch-0.5 inch (0.25 mm-12.7 mm), more narrowly, 1.27-3.81 mm. The air ratio of total opening size to tube cross-sectional area may be so much of that discussed for the embodiment of FIG. **4**.

The separators may also be used as flash tank economizers. FIG. **11** shows an alternate refrigeration system **400** wherein the separator **170** is positioned between first and second expansion devices **402** and **404**. The first expansion device receives refrigerant from the gas cooler and expands the refrigerant. The inlet **174** receives the expanded refrigerant. The first outlet **176** is coupled via an economizer line **408** to the economizer port (intermediate port) **410** of the compressor **412** to deliver the high quality refrigerant. The second outlet **178** is coupled to the second expansion device to deliver the low quality refrigerant. The second expansion device expands the refrigerant for delivery to the evaporator and, thereafter, return to the compressor suction port.

The systems may be fabricated from conventional components using conventional techniques appropriate for the particular intended uses.

Although embodiments are described above in detail, such description is not intended for limiting the scope of the present disclosure. It will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. For example, when implemented in the remanufacturing of an existing system or the reengineering of an existing system configuration, details of the existing configuration may influence or dictate details of any particular implementation. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A system comprising:
a compressor;
a heat rejection heat exchanger coupled to the compressor to receive refrigerant compressed by the compressor;
a heat absorption heat exchanger; and
a separator comprising:
a vessel having an interior;
an inlet;
a first outlet;
a second outlet; and
an inlet conduit extending from the inlet and having a closed lower end and lateral apertures forming a conduit outlet positioned to discharge an inlet flow into the vessel interior to cause the inlet flow to hit a wall before passing to a liquid refrigerant accumulation in the vessel.

2. The system of claim 1 further comprising:
an ejector having:
a primary inlet coupled to the heat rejection heat exchanger to receive refrigerant;
a secondary inlet; and
an outlet,
wherein:
the inlet of the separator is coupled to the outlet of the ejector; and
the second outlet of the separator coupled to the heat absorption heat exchanger to deliver refrigerant to the heat absorption heat exchanger.

3. The system of claim 2 wherein:
the system has no other ejector; and
the system has no other compressor.

4. A method for operating the system of claim 2 comprising running the compressor in a first mode wherein:
the refrigerant is compressed in the first compressor;
refrigerant received from the first compressor by the heat rejection heat exchanger rejects heat in the heat rejection heat exchanger to produce initially cooled refrigerant;
the initially cooled refrigerant passes through the ejector;
an outlet flow of refrigerant from the ejector passes to the separator, forming the liquid refrigerant accumulation with a headspace thereabove; and
the outlet flow becomes the inlet flow into the vessel interior and is deflected from the wall.

5. The system of claim 1 wherein:
the separator is positioned as an economizer.

6. The system of claim 1 wherein:
refrigerant comprises at least 50% carbon dioxide, by weight.

7. The system of claim 1 wherein the wall is an exterior sidewall and the conduit outlet is positioned so that flow is deflected off an inner surface of the wall.

8. The system of claim 1 wherein:
the closed lower end is spaced above a bottom of the vessel.

9. The system of claim 1 wherein:
the lateral apertures are in a mesh or screen across a lateral opening.

10. The system of claim 1 wherein:
the closed lower end is supported by a bottom of the vessel.

11. The system of claim 10 wherein:
the lateral apertures are above the liquid refrigerant accumulation in the vessel interior.

12. The system of claim 11 wherein:
the lateral apertures are in a mesh or screen across a lateral opening.

13. The system of claim 1 wherein a tube has a portion immersed in the liquid refrigerant accumulation and has at least one hole along the portion, at least one hole positioned to entrain liquid from the accumulation in a flow of gas through the tube from a headspace to the first outlet.

14. The system of claim 13 wherein:
the tube is a U-tube having a gas inlet end open to the headspace and extending to the first outlet.

15. The system of claim 1 further comprising:
an expansion device directly upstream of the heat absorption heat exchanger inlet.

16. A system comprising:
a compressor;
a heat rejection heat exchanger coupled to the compressor to receive refrigerant compressed by the compressor;
a heat absorption heat exchanger; and
a separation device having:
an inlet;
a first outlet;
a second outlet coupled to the heat absorption heat exchanger to deliver refrigerant to the heat absorption heat exchanger; and
means for limiting foaming of an accumulation of refrigerant.

17. The system of claim 16 wherein:
the means is means for directing an inlet flow of refrigerant to impact a wall of a vessel of the separation device before encountering the accumulation.

18. A system comprising:
a compressor;
a heat rejection heat exchanger coupled to the compressor to receive refrigerant compressed by the compressor;
a heat absorption heat exchanger; and
a separator comprising:
a vessel having an interior;
an inlet;
a first outlet;
a second outlet; and
an inlet conduit extending from the inlet and having a conduit outlet positioned to discharge an inlet flow into the vessel interior to cause the inlet flow to hit a wall before passing to a liquid refrigerant accumulation in the vessel, the inlet conduit comprising an open end and a deflector between the open end and the accumulation.

19. The system of claim 18 wherein the deflector comprises:
an open end and a spiral deflector at least partially within the conduit.

20. The system of claim 18 wherein the deflector comprises:
a concavity facing the open end.

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